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Extending DER Transient Loadability Using Electrochemical Capacitors

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Project Summary

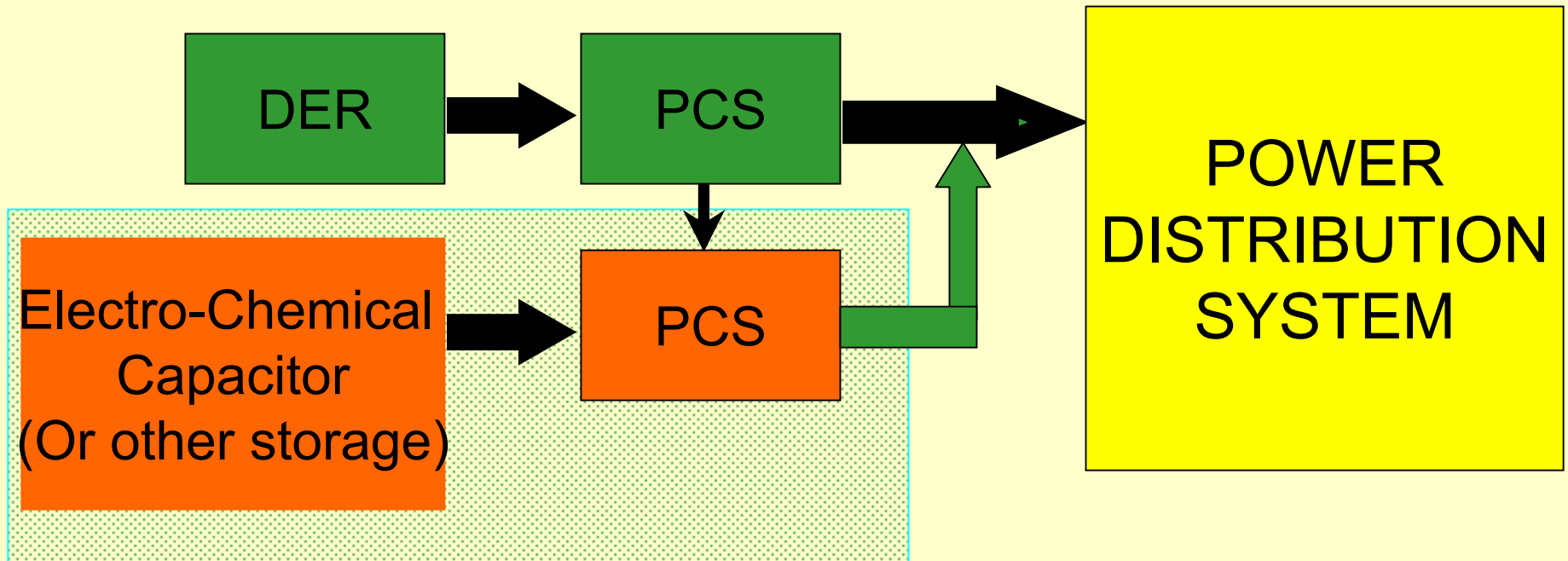
Objective

Distributed Energy Resources (DER) have problems responding to transient load, such as motor start.

- Investigate the use of energy storage to assist DER and improve transient loadability
- Investigate characteristics and applications of electrochemical and double-layer capacitors

SUMMARY

Proposed Device



PCS – Power Conversion System an electronic dc-ac or similar converter

Prior work

- Previously developed simulation model using data for commercial capacitors
- Performed design studies to size capacitor and power conversion system

Project Summary

- Developed specifications for laboratory scale and practical scale system
- Developed a laboratory prototype to demonstrate concept

Presentation Outline

- Motivation
- Overview of Design Study
- Experiment
- Related project

DER AS A TRUE RESOURCE

- Distributed Generation Resources are becoming important components of electric energy supply picture
- Generally designed for grid-connected application--islanded operation still a matter of debate
- Would be a true 'resource' if islanded 'micro-grids' were permitted/viable
- One limitation to viable islands is the need to handle transient loads – starting of a medium or large motor

MOTIVATION

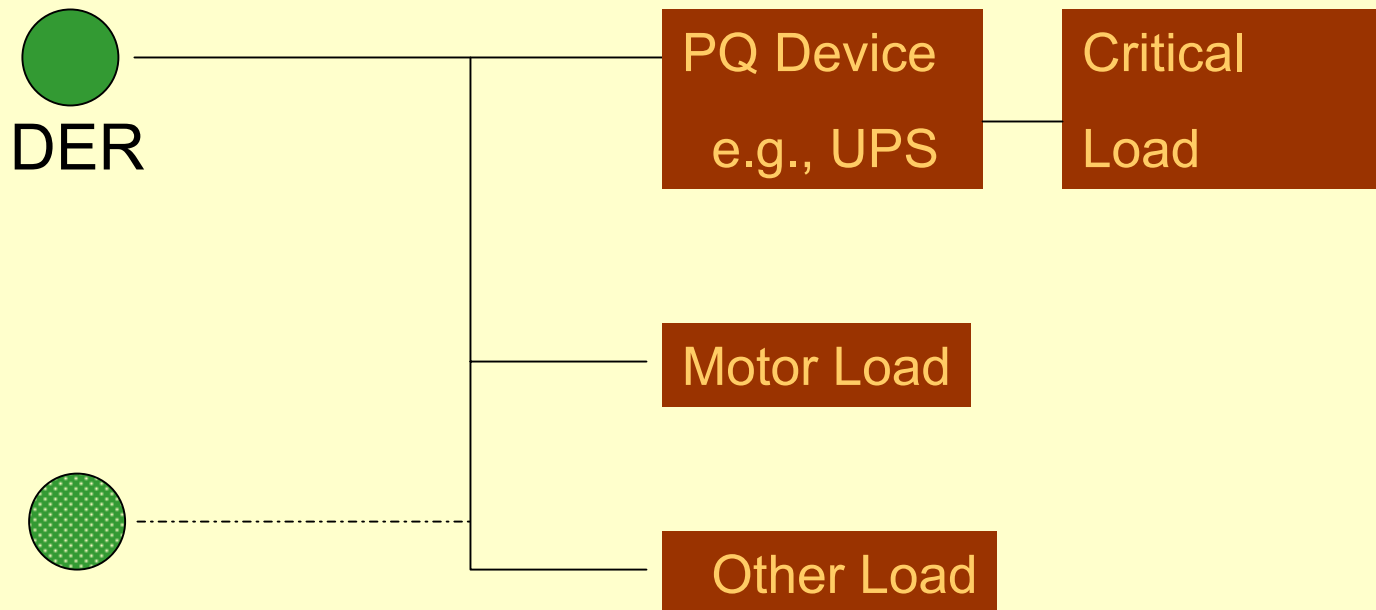
- DER-Load-Utility Interconnection is through an inverter (dc-ac power conversion system PCS)
- Inverter semiconductors are sized to generation capacity plus 25% safety margin(not overload capability)
- ac induction motors require six times the normal current when starting--can exceed PCS capability
- PCS can be designed for some surge capability
- Typical PCS will either reduce voltage or trip

MOTIVATION

- Assume islanded operation is desirable
- With a single DER the voltage quality/availability is compromised
- With an islanded DER cluster the viability of the entire island is compromised

Possible Solutions to Motor Start Problem

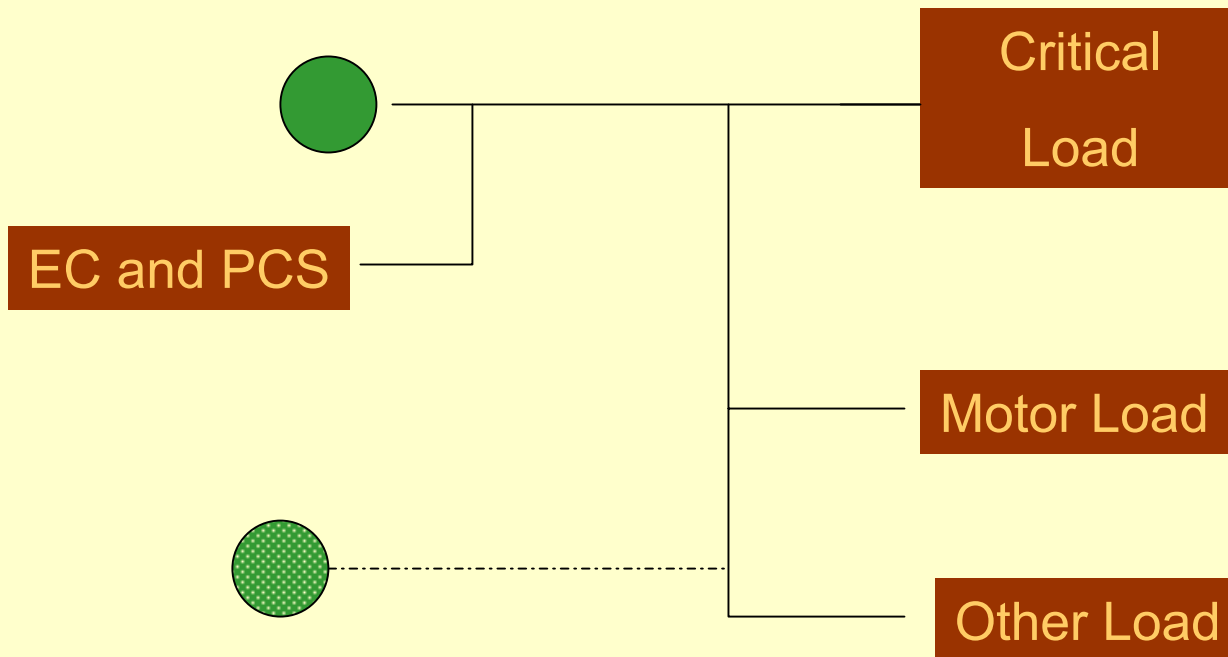
- Conventional-- Load Side



Other load, and other DERS may be compromised

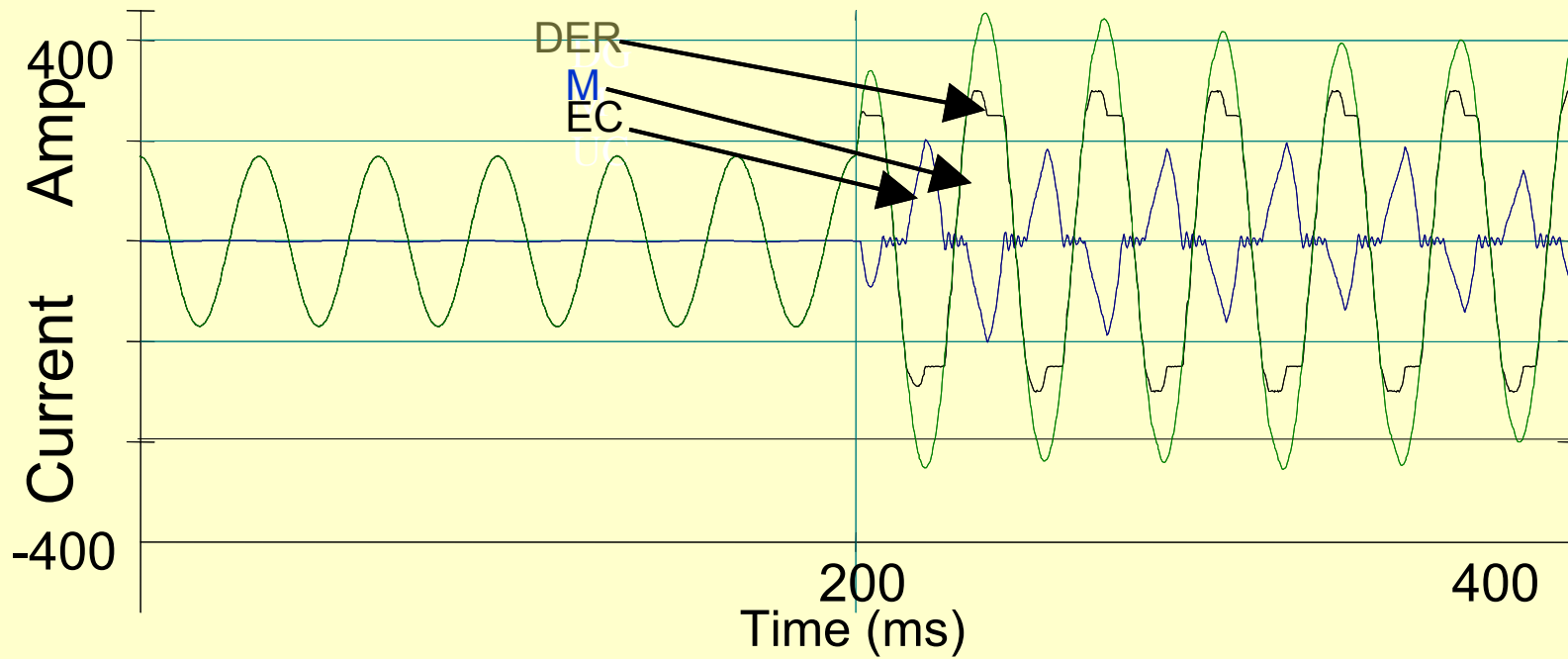
Possible Solutions to Motor Start Problem

- Proposed-- DER Side

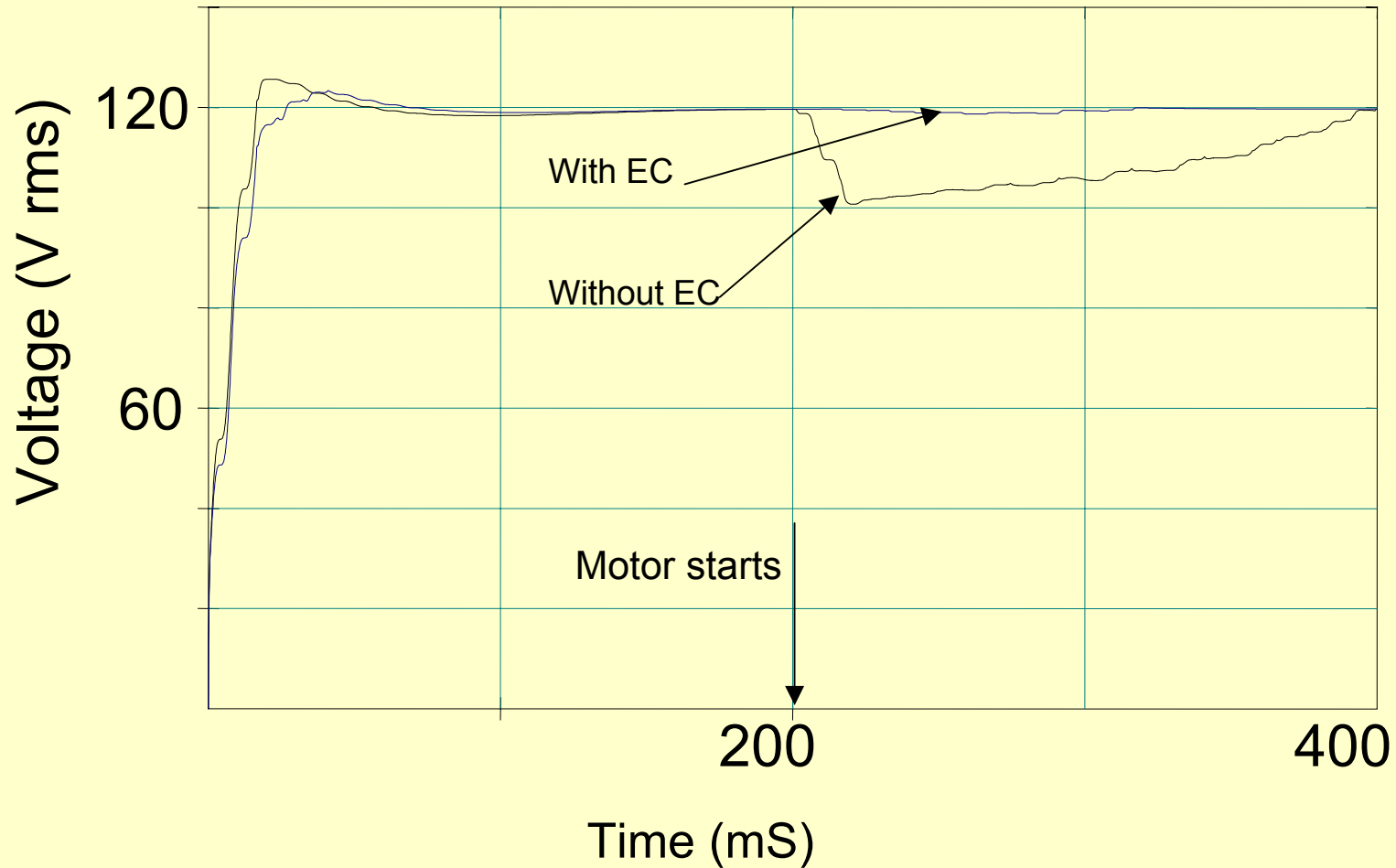


EC provides supplementary current to sustain DER

Proposed Approach



Proposed Approach



Advantages of EC Capacitors

- High Specific Energy- Small Footprint
- High Specific Power
- Low Maintenance
- Wide temperature range

Disadvantages of EC Capacitors

- High resistance— have to charge to a higher voltage
- Lossy
- Higher voltage implies difficulty charging

EC Capacitor Sizing

- Developed a system model
- Assumed ideal micro-turbine
 - modeled PCS only
- Alternative Transients Program (ATP)
- Capacitor Model from Dr. John Miller
- Looked at starting a very Large motor — 40 HP

RESULTS

- 75 kW 120/208 V DER
- Assume starting 10-40 HP motor
- EC Capacitor
 - 0.5-1 F, ESR 0.1 ohm
 - dc bus 400-600V dc

Design Using Commercial Capacitors

160 F capacitor

26 V

ESR 0.01 ohm

1 string

- 19 units 494 V rating
- 8.4 F capacitance
- 745 kJ
- \$ 37,000¹

320 F capacitor

13 V

ESR 0.006 ohm

1 string

- 42 units 542 V rating
- 7.6 F capacitance
- 850 kJ
- \$ 42,000¹

¹ Source: Tom Key (EPRI-PEAC) -- \$50/kJ

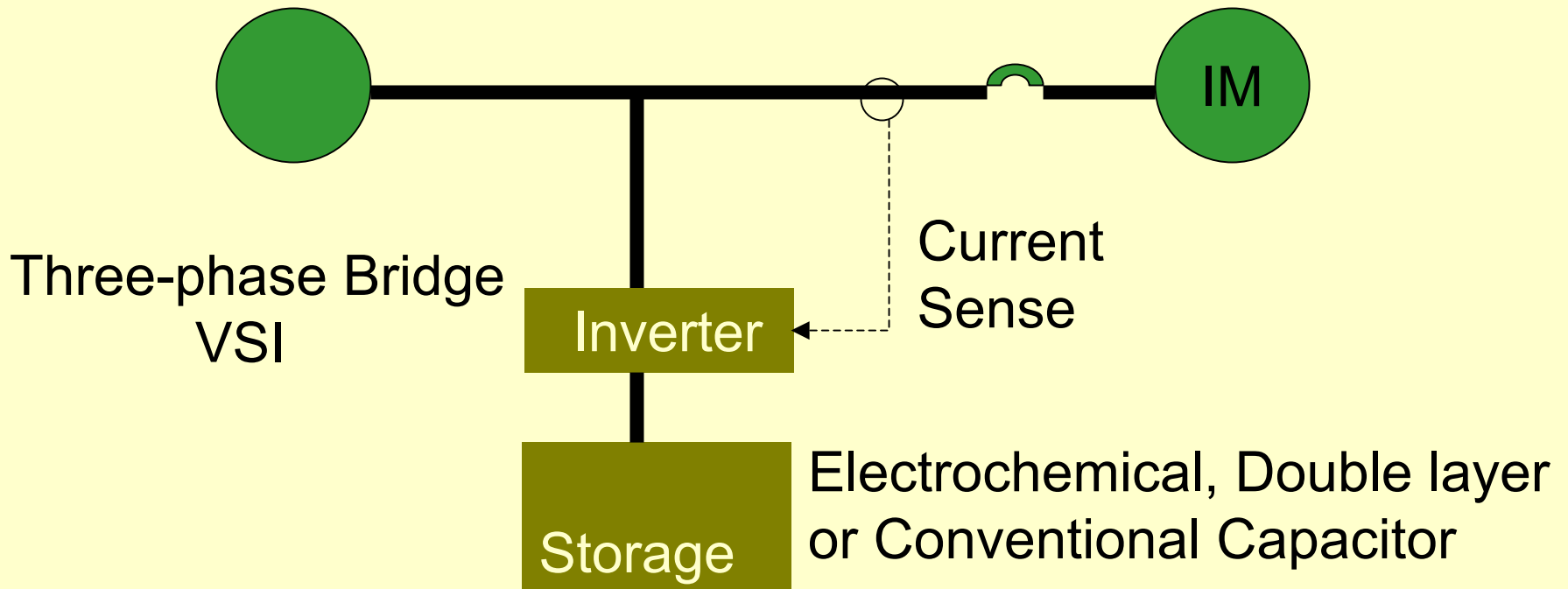
Design Using Commercial Capacitors

- For the commercial technology considered, the desired ESR corresponds to higher capacitance and energy than needed
- Energy requirement is easily met (40 HP motor estimated to require 250 kJ)
- Costs can be reduced if ESR could be maintained within 0.1-0.2 ohmf for a 400-600 V 1-3 F capacitor, depending on motor size.

Experiment

Single or Three-phase
208/120 V, 60 Hz, ac source
(Simulates DER)

Single or Three-phase
Induction Motor
(1/12 – ½ HP)



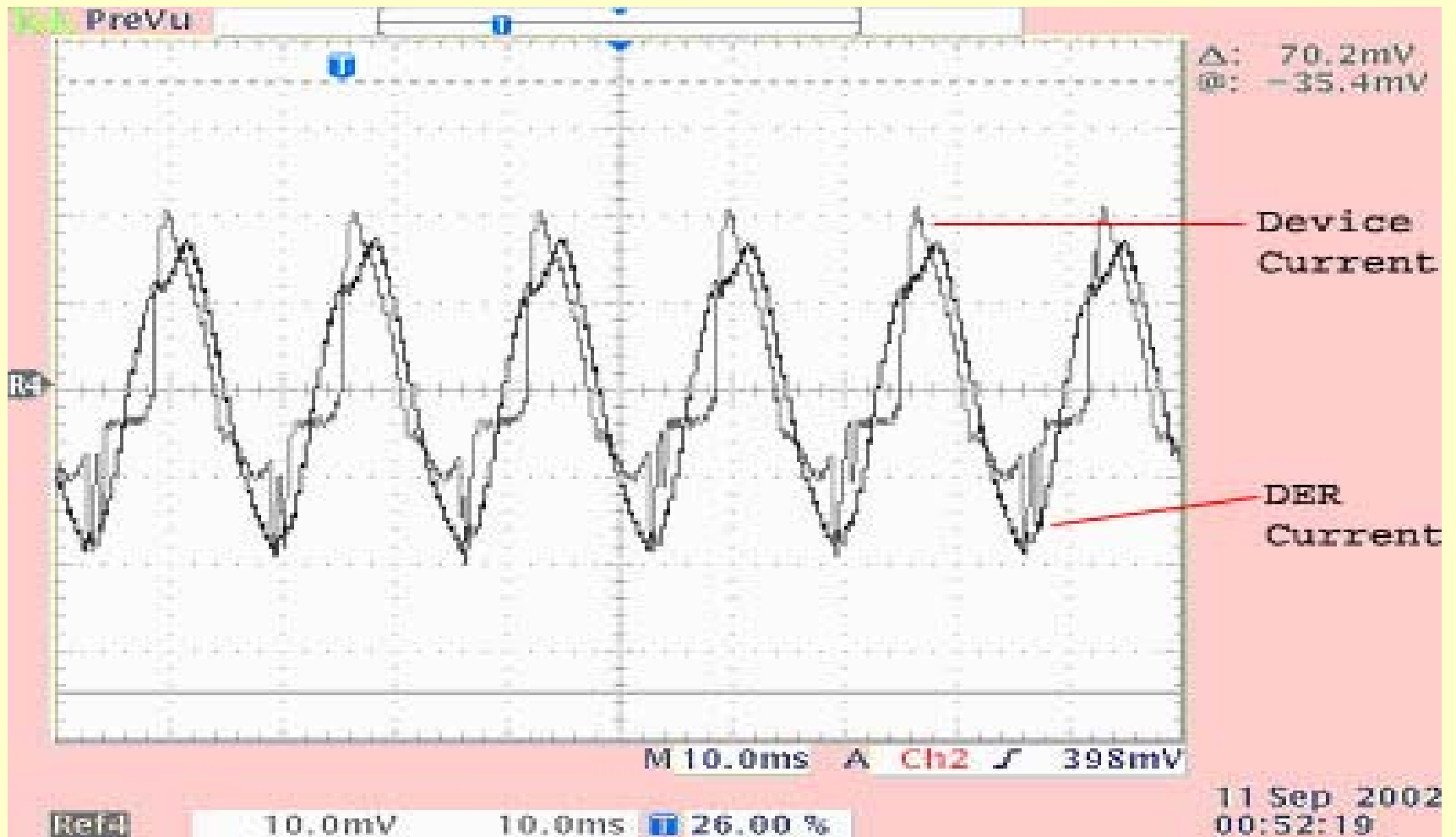
Experiment-Capacitors

- Electrochemical
- ESMA 30EC402
- 42/21 V
- ESR 0.009 ohm
- 220 kJ /330 F
- Double Layer
- Maxwell PC10
- 2.5 V
- 10F
- String of 80
- 200V, .125 F
- 1.875 kJ, 50% discharge

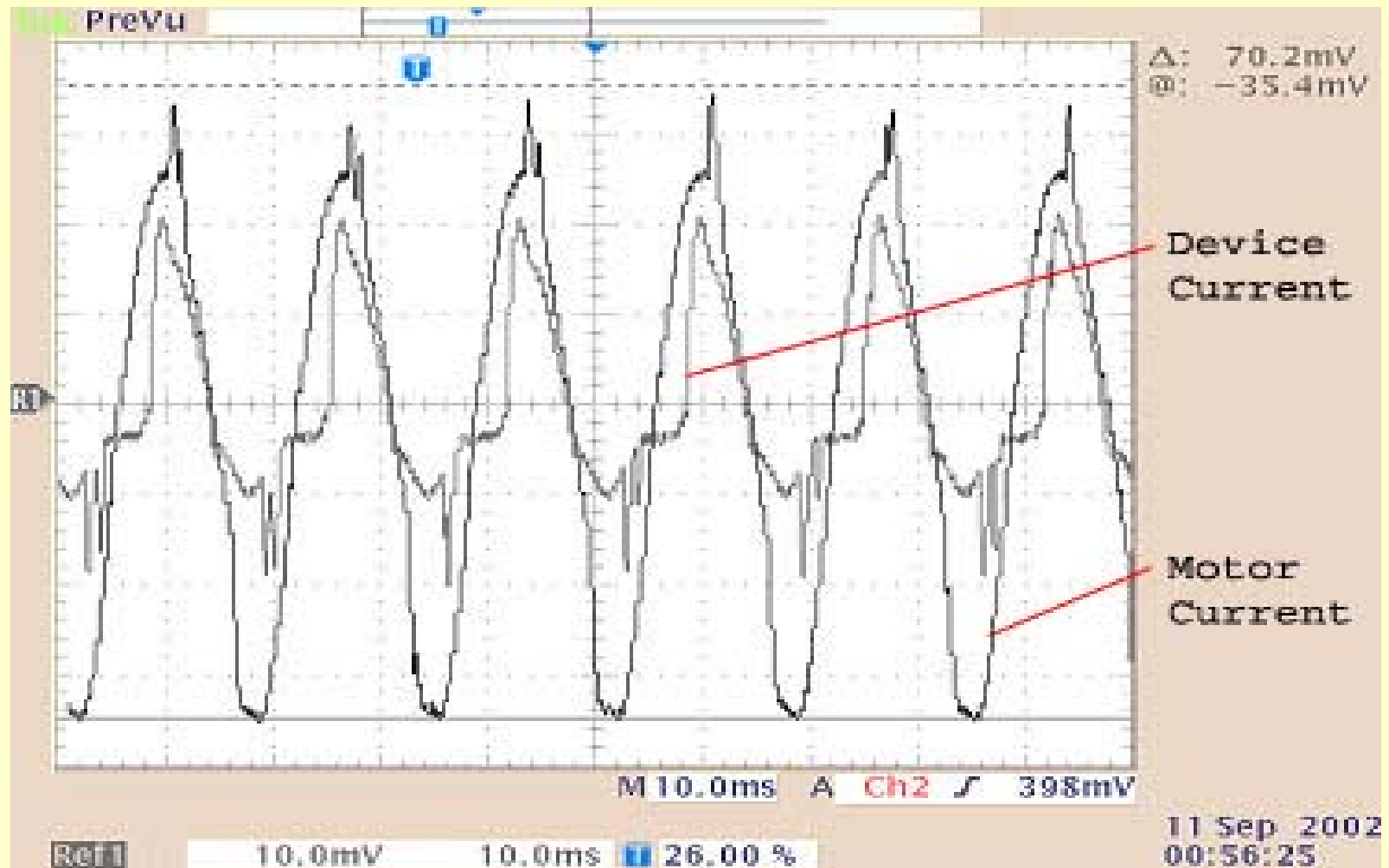
Experiment-Control

- Open Loop Scheme
- PCS provides a current pulse whenever
 - motor (load) current exceeds DER capability.
- Current Magnitude depends on capacitor SOC and System Voltage
- Nominally designed to prevent DER trip

Experiment-Results



Experiment-Results



RESULTS

- The concept is technically feasible.
- If proper combination of Capacitance/ESR were available the cost might be 15% of DER cost (700-1200 \$/kW) installed.
- A breadboard prototype has been demonstrated

Status

- Fabricating Final Prototype
- Better understanding of capacitor behavior
- Design for voltage/power level compatible with practical DER
- Disclosed as a TA

Related Work--Capacitor Characteristics

Capstone project for students

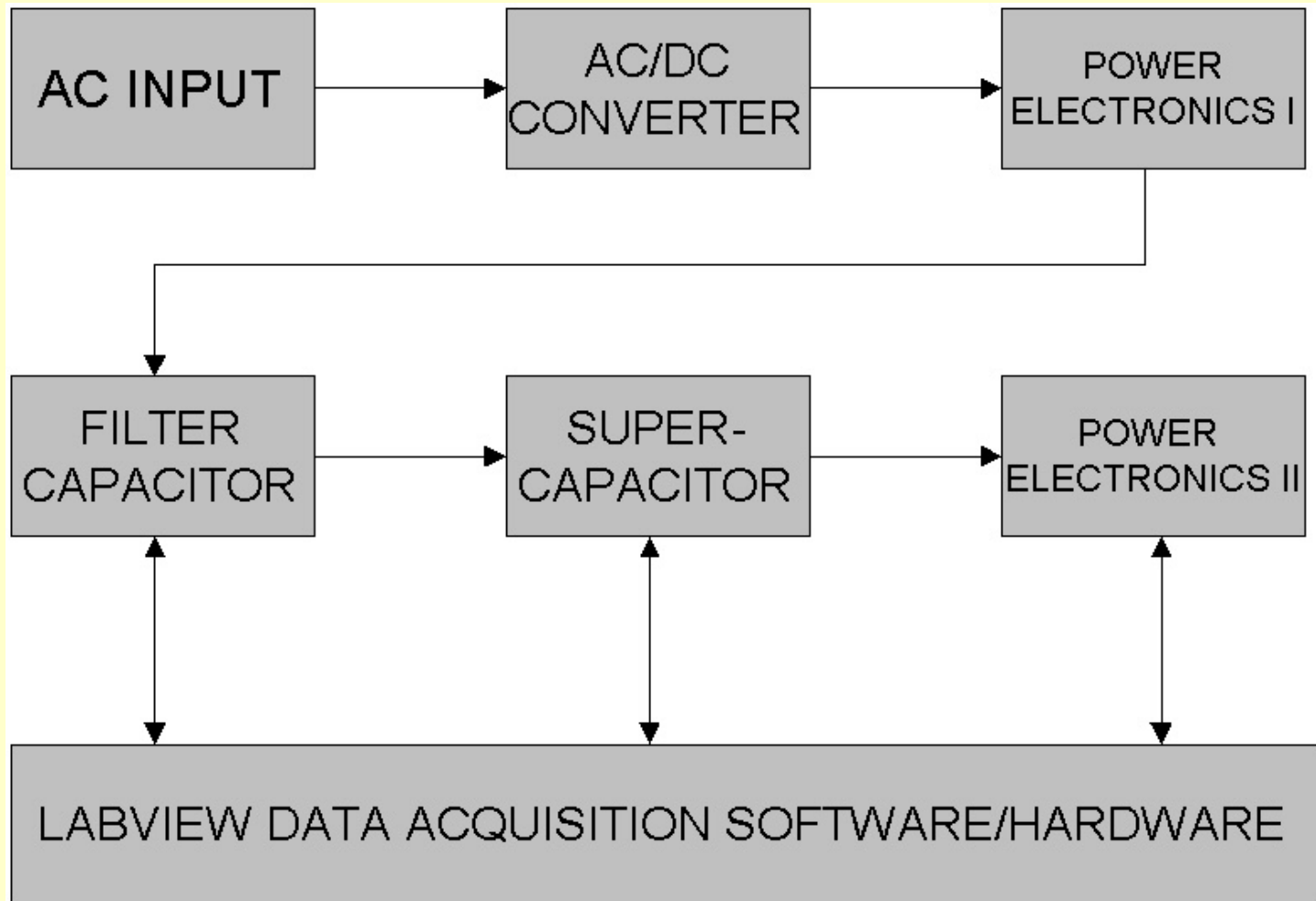
- Capstone- Terminal 6-credit design class
- Industry/Government/Faculty team publishes 'RFP'
- Students form team and prepare 'Proposal'
- Students complete design project tasks and prepare report and make a presentation

Related Work--Capacitor Characteristics

Capstone project for students

- DOE ESS sponsored capstone under SNL Management
- Develop a system to test charge/discharge characteristics of capacitors
- System will help understand capacitor application considerations
- Excellent way to introduce students to technology!

Capacitor Characteristics



CONCLUSIONS

- Proposed a device that augments DER capability
 - Makes DER more attractive
- DER based solution will allow DER to supply transient loads
- Allow viable DER islands
- Laboratory prototype demonstrated